Convective-scale Warn-on-Forecast:
The Severe Weather Forecast Improvements Project

Summary of Year One Research Activities

March 2010 through February 2011

Executive Summary

Increasing lead time and accuracy for hazardous weather and water warnings and forecasts in order to reduce loss of life, injury, and damage to the economy, is one of the main objectives of the weather and water strategic mission goal for the National Oceanic and Atmospheric Administration (NOAA). Trends in yearly-averaged tornado warning lead time suggest that the present weather warning process, largely based upon a *warn-on-detection* approach using National Weather Service (NWS) Doppler radars, is reaching a plateau and further increases in lead time will be difficult to obtain. A new approach is needed to extend warning lead time in which probabilistic hazard guidance is provided by an ensemble of forecasts from convection-resolving numerical weather prediction models. This convective-scale probabilistic hazardous weather forecast system is called *warn-on-forecast*.

This document summarizes the research efforts that will be conducted during the first year of the warn-on-forecast project from March 2010 through February 2011. These efforts are largely pointed towards laying the foundation for the program's success, such as identifying and hiring needed staff, surveying prior research, and the development of code and other infrastructure needs. As such, some of these activities may not have many direct outcomes during this first year.

The activities of each organization that receives funding from the warn-on-forecast project are summarized in the following sections, along with any deliverables. This document is required as part of the annual planning process for the project and is an important component of the project management structure.

The warn-on-forecast project represents a collaborative effort across several NOAA units and academia. The project is led by the National Severe Storms Laboratory, with substantial NOAA contributions from the Earth System Research Laboratory, the Storm Prediction Center, and the Norman NWS Forecast Office. Academic collaborators are the Center for Analysis and Storms and the Social Sciences Woven into Meteorology Program within the Cooperative Institute for Mesoscale Meteorological Studies at the University of Oklahoma.

Year One Research Activities

NOAA/OAR/National Severe Storms Laboratory

During the first year of the warn-on-forecast project, the National Severe Storms Laboratory proposes to accomplish the following tasks:

- Hire a federal scientist with expertise in data assimilation for convective scales with expertise in the use of radar data to help lead the warn-on-forecast efforts.

- Develop "baseline" quality controlled data sets for use in assimilation and quality control (QC) algorithm testing. This work involves the "manual" (human editing) of radar data to fix velocity de-aliasing errors and the removal of reflectivity artifacts. Each case may have data from multiple WSR-88D radars. We will also gather supplemental data sets for each case, such as model analyses and forecasts, surface and upper-air observations, and satellite data.

- Begin a survey of automated QC methods.   Initially, we will survey the field to determine the full range of currently available QC solutions. These may include, but are not limited to: 2D velocity de-aliasing algorithms, reflectivity QC methods, and near-future operational techniques such as dual-polarization clutter mitigation and (eventually) staggered PRT.   Strengths and weaknesses of each technique will be highlighted, and we will collect source code and implement into a common framework for side-by-side testing when possible.

- Develop a framework for examining assimilated fields and derived products, provided by the CAPS using a three-dimensional variational assimilation (3DVAR) system, in the Hazardous Weather Testbed (HWT) or post-analysis. Monitor, analyze, and provide feedback to CAPS regarding this data stream. Compare products to radar-based and other multi-sensor fields to assess realism and develop documentation for potential end-users (e.g. forecasters) of the data.   Present data to visiting forecasters and other collaborators in the HWT.   Continue development of ideas for data presentation and future changes to the warning paradigm (probabilistic hazard information).

- Begin real-data case studies using an ensemble Kalman filter to assimilate WSR-88D and other routine observations into a ~2 km grid spacing configuration of the Weather Research and Forecasting (WRF) model using the Data Assimilation Research Testbed (DART) square root filter software developed at the National Center for Atmospheric Research.

- Begin studying the predictability of severe thunderstorms by examining the uncertainty of the environments known for producing severe convective thunderstorms.

- Collaborate with the other project partners in exploring complex issues related to the frequent updating of convective-scale models, both deterministic and ensemble systems.

- Lead effort with other warn-on-forecast partners to develop a unified plan for social science research activities.

- Complete the data collection activities of the Verification of the Origin of Rotation in Tornadoes Experiment 2 (VORTEX2) in collaboration with many other institutions. Provide experiment forecast support as needed.

- Develop a warn-on-forecast webpage.

Deliverables:

- Quality controlled and supplemental data sets for 5 June 2009 VORTEX2 case (5 radars for ~4 h each) completed and available to project partners. Document the manual analysis method.

- Summary report detailing the available automated quality control techniques and an assessment of the strengths and weaknesses of each.

- Report detailing the CAPS real-time three-dimensional variational assimilation (3DVAR) system, the products provided, and an assessment of 3DVAR system performance by forecasters and other storm experts.

- Archival of the CAPS 3DVAR assimilated fields and corresponding data sets (radars, etc.) from real-time operations.

- Written plan to unify the social science research activities within the warn-on-forecast project.

- New federal scientist hired to assist in data assimilation activities.

- Completion of VORTEX2 field phase data collection activities.

- Warn-on-forecast webpage completed and online.

NOAA/OAR/ESRL/Global Systems Division

During the first year of the warn-on-forecast project, the Global Systems Division proposes to accomplish the following tasks:

- Develop code necessary to provide forecast output from the High-Resolution Rapid Refresh (HRRR) model every 15-min during the 0-3 h forecast time period. These 15-min output files will be used to provide boundary conditions for warn-on-forecast model ensemble testing and evaluation.

- Direct application of the Digital Filter Initialization (DFI) radar-based technique at the 3-km resolution of the HRRR will be tested. Explore the DFI approach when radar data at multiple times are used in the assimilation window.

- Develop an initial design for ensemble Kalman filter (EnKF) data assimilation at the storm-scale using the HRRR model and collaborate with NSSL and CAPS in the planning process for this test environment. The added value of the HRRR-EnKF system will be assessed relative to the HRRR-DFI approach.

- Hire a federal scientist with expertise in data assimilation for convective scales with expertise in the use of radar data to help lead the warn-on-forecast efforts.

- Collaborate with the other project partners in exploring complex issues related to the frequent updating of convective-scale models, both deterministic and ensemble systems.

- Compute model-to-observation statistics for the Rapid Refresh/HRRR models using observations provided by the Meteorological Assimilation Data Ingest System (MADIS) and incorporate the statistics into the National Mesonet metadata database along with the station and instrumentation information. These metadata will be used to form observation "use lists", from which the observations to be ingested into data assimilation systems can then be determined.

- Document the operational procedures and uses of current AWIPS and N-AWIPS capabilities and functionality that support operational severe weather watch and warning programs.

- Prototype a framework sufficient to perform an initial displaced real-time evaluation of warn-on-forecast techniques and capabilities.

- Work with warn-on-forecast partners to develop a unified plan for social science research.

Deliverables:

- HRRR gridded forecast output produced at 15-minute intervals during the 0-3 h forecast time frame and made available to project partners.

- Improved "use lists" for observations collected by MADIS as determined by model-to-observation statistics calculated using the RR/HRRR models and made available to project partners.

- Report documenting current WFO and SPC practices for determining and generating severe weather watches and warnings.

- Collection of warning and verification information from selected WFOs.

- Prototype displaced real-time evaluation system for warn-on-forecast that can be used to assess techniques and capabilities.

- New federal scientist hired to assist in data assimilation activities.

NOAA/NWS/NCEP/Storm Prediction Center

During the first year of the warn-on-forecast project, the Storm Prediction Center proposes to accomplish the following tasks:

- Hire a joint institute research scientist to assist in the evaluation of warn-on-forecast products and services within the Hazardous Weather Testbed.

- Work with other warn-on-forecast partners to develop a unified plan for social science research.

- Begin discussions on how to best evaluate warn-on-forecast approaches and techniques within the Hazardous Weather Testbed with project partners.

Deliverables:

- New joint institute research scientist hired to assist in HWT activities.

NOAA/NWS Norman Forecast Office

During the first year of the warn-on-forecast project, the NWS Norman Forecast Office proposes to accomplish the following tasks:

- Hire a joint institute research scientist to assist in the evaluation of warn-on-forecast products and services within the Hazardous Weather Testbed.

- Work with other warn-on-forecast partners to develop a unified plan for social science research.

- Begin discussions on how to best evaluate warn-on-forecast approaches and techniques within the Hazardous Weather Testbed with project partners.

Deliverables:

- New joint institute research scientist hired to assist in HWT activities.

University of Oklahoma/Center for Analysis and Prediction of Storms

During the first year of the warn-on-forecast project, the Center for the Analysis and Prediction of Storms proposes to accomplish the following tasks:

- Enhance the ARPS EnKF system for multi-scale observations (e.g., radar, surface and upper-air) and evaluate it using one of the VORTEX2 cases. This EnKF system uses the ensemble square root algorithm (EnSRF).

- Develop a hybrid 3DVAR-ensemble system based on the ARPS 3DVAR and ARPS EnKF and evaluate the performance relative to the pure 3DVAR and pure EnSRF algorithms.

- Develop a local ensemble transform Kalman filter (LETKF) system and implement it within the ARPS EnKF framework. Inter-compare the performance and computational costs of LETKF and EnSRF algorithms for the convective-scale radar data assimilation problem.

- Develop an interface for the ARPS EnKF data assimilation system with Advanced Research WRF (ARW) model.

Deliverables:

- Enhanced ARPS EnKF system for multi-scale observations (e.g., radar, surface and upper-air) completed and testing started.

- A local ensemble transform Kalman filter (LETKF) system completed and implemented within the ARPS EnKF framework.

- An interface for the ARPS EnKF data assimilation system with Advanced Research WRF (ARW) model completed and made available to project partners.

University of Oklahoma/Social Sciences Woven into Meteorology Program

During the first year of the warn-on-forecast project, the Social Sciences Woven into Meteorology Program proposes to accomplish the following tasks:

- Identify and hire a graduate research assistant to support social science research within the warn-on-forecast project.

- Conduct a literature review of public understanding of probabilities and the value of weather information, including some relevant risk perception literature.

- Design the interview protocol based on the questions that are identified in the literature review and identify the population to be interviewed.

- Work with other warn-on-forecast partners to develop a unified plan for social science research.

Deliverables:

- New graduate research assistant hired to support social science research.

- Report on literature review of the public understanding of probabilities and the value of weather information.